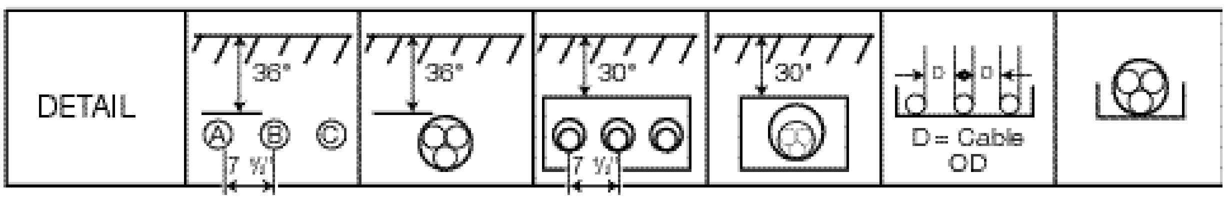
ICEA Ampacities

ICEA Ampacities (Insulated Cable Engineers Association)

Ampacities shown in this table are based on the values published in ICEA Publication P46-426 Volumes I and 11. Ampacities shown are for 15kV cables. Ampacities at other voltages for shielded cables do not vary significantly. For adjustments in conductor or ambient temperatures refer to the next page of this section.

Parameters

Conductor Normal Operating Temperature: 90°C
Air Ambient Temperature: 40°C
Earth Ambient Temperature: 20°C
Soil Thermal Resistivity (RHO): 90°C—cm/watt
Load Factor: 100%
One Isolated 3 Phase Circuit
Single Conductor Cable: Open circuit, shield/ground/armor
3 Conductor Cable: Short circuit, shield/ground/armor
5" Duct
No wind and no solar radiation in tray



CONDUCTOR SIZE AWG/ kcmil	COPPER CONDUCTORS					
	DIRECTLY BURIED		IN BURIED DUCT		IN VENTILATED TRAY	
	3 SINGLE CABLES	3 CDR CABLE	3 SINGLE CABLES	3 CDR CABLE	3 SINGLE CABLES	3 CDR CABLE
2	210	184	179	150	195	164
1	240	209	204	171	225	187
1/0	274	238	232	194	259	215
2/0	312	270	265	220	298	246
3/0	354	307	302	250	343	283
4/0	403	348	344	284	397	325
250	442	382	378	311	440	359
350	534	458	457	374	543	438
500	649	549	557	449	678	536
750	805	667	695	545	872	669
1000	932	752	807	613	1040	770
ALUMINUM CONDUCTORS						
2	164	143	139	117	152	128
1	187	163	159	133	175	146
1/0	213	185	181	151	202	168
2/0	243	211	206	172	232	192
3/0	276	240	235	196	268	221
4/0	314	272	268	222	310	254
250	345	299	295	244	343	281
350	417	360	357	294	424	344
500	508	435	436	356	531	424
750	634	538	547	440	687	539
1000	740	619	641	506	826	634

Note: Special approval by the local electrical inspection authority may be required for the use of ICEA ampacity ratings (Ref CE Code Part 1 Rule 4-004 Appendix B)

Dimensions and weights are nominal; subject to industry tolerance.

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ICEA Ampacities

Adjustments for Changes in Temperatures

Ambient Temperature:

The ampacity values shown on page 207 are based on 90°C normal conductor operating temperature. The ambient temperatures for direct burial (or in duct) and in air installations are 20°C and 40°C respectively. To obtain the corresponding ampacity at an ambient temperature other than above while still maintaining the aforementioned conductor temperature, use the following equation:

$$I' = I \sqrt{\frac{90 - T_a'}{90 - T_a}} \text{ amperes} \qquad \text{(Formula 1)}$$

Where:	I'	=	adjusted ampacity for ambient temperature T_a', amperes.
	I	=	ampacity at 90°C conductor temperature and old ambient temperature T_a, amperes.

Conductor Temperature:

To find the ampacity of a cable at a conductor temperature other than 90°C, the following equation is used:

$$I' = I \sqrt{\frac{T_c' - T_a'}{T_c - T_a} \times \frac{\bar{T}_c + T_c}{\bar{T}_c + T_c'}} \text{ amperes} \qquad \text{(Formula 2)}$$

Where:	I'	=	ampacity at new conductor temperature T_c', amperes
	I	=	ampacity at old conductor and ambient temperatures T_c and T_a respectively (amperes)
	T_c'	=	new conductor temperature (°C)
	T_a'	=	new ambient temperature (°C)
	T_c	=	old conductor temperature (°C)
	T_a	=	old ambient temperature (°C)
	$\bar{T}_c$	=	inferred temperature of zero electrical resistance (°C)
		=	234 for copper
		=	228 for aluminum

CSA Technical Section

As noted for Products Manufactured to CSA Standards

This page has been prepared as a supplement in order to assist our customers in selecting the right cable for the job. National and Provincial electrical inspection regulations are based on the Canadian Electrical Code Part 1 Rules.

We have attempted to address the most common technical questions concerning the application and handling of the cables. General Cable's technical staff would be happy to assist with any special concerns you may have with installation of our products.

Product Warning Notice

Risk		Description
	Flammable	• Cables will burn and may transmit fire.
	Toxic	• Toxic gas may be formed from burning cables. • Do not breathe fumes or enter area until well ventilated.
	Corrosive	• Burning cables may form acid gases. • Do not enter area until well ventilated. • Metals in the vicinity of burning cables may corrode.
	Smoke	• Burning cables may release dense smoke which may impede fire suppression.

- Burning cables may cause loss of life, personal injury, damage to property and may inhibit fire suppression efforts.
- Risks increase when
  - cables are grouped
  - cables are installed in facilities which fail to comply with good engineering practices relating to fire protection, electrical systems, operating and maintenance practices (the "Engineering Practices")
- Expert advice must be sought in relation to the Engineering Practices to minimize all risks.

This notice supercedes all references to the characteristics of this cable and must be brought to the attention of those involved with the use of cables.

CSA Technical Section

Flame Tests

Flame Test Requirements:

All of General Cable's products as indicated meet the flame test requirements of CSA.

There are basically two CSA classifications (levels) of tests currently in use which are detailed in CSA Standard C22.2 No. 0.3 (Test Methods for Electrical Wire and Cable), which apply to products shown in this catalog.

CSA Classification*	Fire Test Procedure	Standard Criteria
FT1	Clause 4.11.1 0.6 meter length Bunsen Burner Vertical Flame Test	Burning shall cease within 60 seconds and not more than 25% of the kraft paper indicator at top of sample shall burn after five 15 second flame applications (approximately 3 minute test).
FT4	Clause 4.11.4 2.3 meter lengths of grouped cable in tray, 70,000 BTU Propane Burner Vertical Flame Test	Burned portion of samples measured after 20 minutes of flame application. Maximum length of char 1.5 meters (20 minute test).

CSA Flame Test Classification for Construction Products

FT1	FT4**
NMD90 Nylon	ACWU9O
NMWU	TECK90
T90 Nylon	HVTECK
TW75	RA90
TWU	TC

The Canadian Electrical Code Part 1 (17th edition) Rule 2-128, states as follows:

> "Flame spread requirements for electrical wiring and cables (see Appendix B). Electrical wiring and cables installed in buildings shall meet the flame spread requirements of the National Building Code or local building legislation."

The appendixed note B to the rule is provided for information and clarification purposes only and is interpreted as follows for your convenience:

FT1 Buildings permitted to be of combustible construction may be wired with FT1 classified non-metallic sheathed cable, or methods permitted in noncombustible buildings mentioned below.

FT4 Buildings required to be of noncombustible construction may be wired with FT4 classified cable, or non-classified wires installed in totally enclosed noncombustible raceways (metal conduits), including areas defined as plenum spaces.

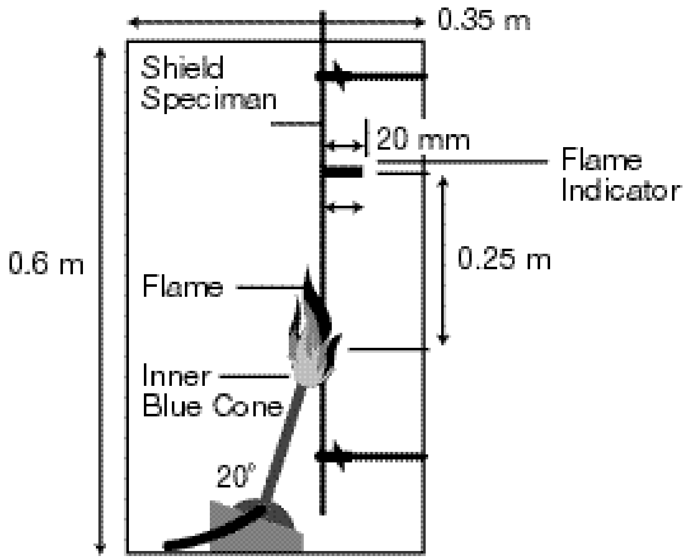
Under fire conditions, TECK90, HVTECK and RA90 cables, without the optional overall PVC covering, are considered to behave similarly to building wires installed in metal conduit.

Note: When single conductor armored cables are used without an overall PVC covering, the effects of circulating current in the armor must be considered.

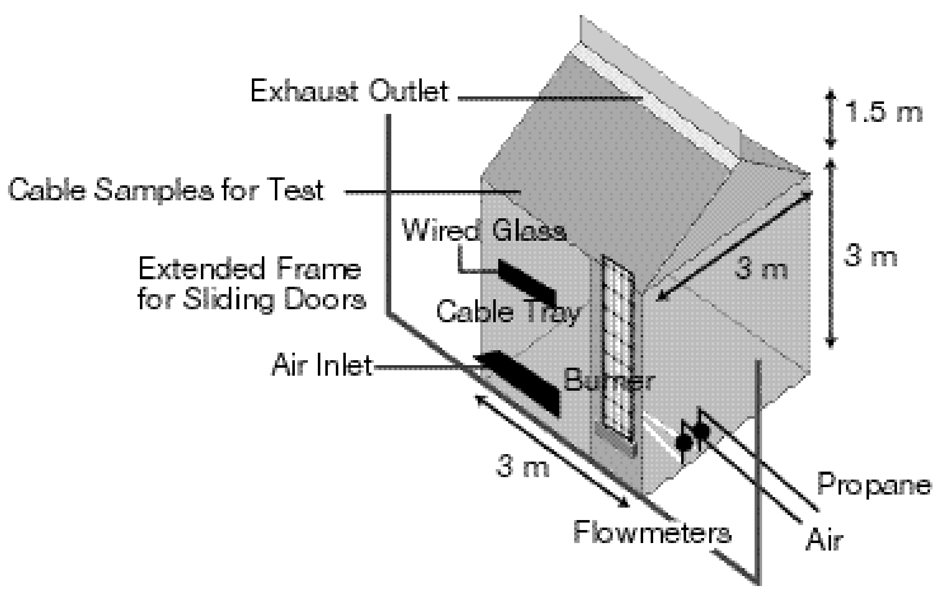
Note: For detailed information on local codes and regulations which may differ from the above, consult your local Electrical Inspection Authority.

CSA Technical Section

CSA Vertical Flame Test "FT1"



CSA Vertical Flame Test "FT4"



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CSA Technical Section

Acid Gas Test

In addition to the FT4 Vertical Flame Test, General Cable tests for Acid Gas Evolution.

During a fire certain gases are released as by-products of combustion, including toxic and corrosive Hydrogen Chloride Gas (HCl).

In order to measure the amount of HCl evolved, each component is rested in accordance with Clause 4.31 of CSA Standard C22.2 No. 0.3. Specimens of the insulation and jacket (if used) are thermally decomposed and the gases analyzed.

The acid gas produced is expressed as a percentage of weight (mass) of the original specimen. The typical maximum permitted percentage is 14%.

General Cable's registered trademark ACID-FLAME-CHECK ✓✓® identifies cables which meet the standard criteria for FT4 and which have emissions of acid gas less than 14%.

CSA Technical Section

HL Marking

In accordance with Section 18 of the Canadian Electrical (CE) Code Part 1, General Cable uses the legend “HL” to identify products suitable for Class I, Division I locations.

Cables with bundled subassemblies that comply with the requirements of CSA C22.2 No. 174-M1984 section 4.3, shall be marked “HLX*”.

*The final letter(s) of the marking shall signify the types of atmosphere (group designation A, B, C, D, or a combination thereof [CE Code Part I Section 18-050]) for which the cable has been tested.

Colored PVC Jackets for Outdoor Use

All polymeric materials undergo degradation when exposed to sunlight. Ultra violet rays, environmental and geographical conditions advance oxidation, crazing, and cracking of all rubber and plastic coverings. For this reason General Cable recommends a **BLACK** outer covering where the cable will be continuously exposed to sunlight.

CSA Technical Section

WHMIS Notice

Workplace Hazardous Materials Information System Notice

We have reviewed the Workplace Hazardous Materials Information System (WHMIS) legislation and concluded that wire & cable products manufactured by General Cable do not fall within the scope of the "controlled products", as defined by the federal legislation; and in fact, are exempt from the WHMIS classification under Manufactured Article as defined in the Bill C-70 Act, dated June 30, 1987.

Although our wire and cable products are not controlled under the WHMIS legislation and thus, do not require corresponding Material Safety Data Sheets (MSDS's), such information for individual materials used in the manufacture of our products can be supplied if requested. These Material Safety Data Sheets have been made available to us by our raw material suppliers. Should you desire further information or have question on this subject, please contact your General Cable Sales Representative.

CSA Technical Section

Insulation Shielding

5kV TECK90 (Unshielded) & 5kV HVTECK (Shielded)

The following discussion addresses a subject frequently raised by our customers. It is intended to acquaint you with some of the factors which may influence the choice of cable that best meets your needs.

5kV Unshielded Cable
Based on CE Code Rule 36-104, insulation shielding is *optional* on all metal sheathed or metal armored cables operating at 5kV or less. The interlocked metal armor of TECK cable serves as mechanical protection for the cable. This bonded (grounded) armor also protects personnel from shock hazards (which would exist if 5kV insulated conductors were left exposed), thus satisfying the intent and requirement of the CE Code Rule.

Controlled voltage distribution within the insulation is essential in medium and high voltage cable. Electrical Stress (volts per mil) is controlled (minimized) by conductor size selection and by design of the insulating layer, both of which are established by the CSA Standards. Both 5kV Shielded HVTECK Cable and 5kV Unshielded TECK90 Cable employ 90 mils of insulation. Shielding is optional because 90 mils of insulation is sufficient to keep the Electrical Stress to a low acceptable level.

Certain commercial factors influence the use of Unshielded 5kV TECK90, making it a standard product:

— Lower cost than shielded cable
— Less diameter and weight
— Smaller bending radius (important in confined equipment)
— Lower termination and splicing cost (no stress relief kits required)
— Stock material (a benefit where availability and shorter lengths are required)

5kV Shielded Cables
Except under special circumstances and unless the cable is installed in a metallic raceway (e.g. rigid metal conduit or interlocked armor) 5kV cables must be shielded. Shielding should also be considered where any of the following conditions exist:

— all unarmored cables rated over 2000 volts
— where a safety hazard exists
— where cables are exposed to induced voltages or potential flashover from adjacent overhead lines or lightning discharges (e.g. terminal poles)
— where the “insulation” is exposed to moist or polluted atmospheres
— to help reduce radio or communication interference*

*It is important that control, signal and instrumentation (data) cables are independently shielded from unwanted electrostatic noise. Electrostatic shielding between units within the cable and around each cable must be provided. Power cable shielding will not provide adequate protection from power frequency and switching interference on neighboring circuits.

CSA Technical Section

Insulation Levels

Cables rated at 5kV

Design of cable insulation takes into account the required physical properties in addition to the electrical properties. At lower voltages the insulation thickness exceeds the electrical requirement due to the demand for mechanical ruggedness. Large sizes of 1000 volt and 5kV TECK90 cables have the same insulation thickness. Shielded HVTECK and Unshielded TECK90 at 5kV (#6 - 1000 MCM) both have 90 mils of insulation and cables with 90 mils of insulation are suitable for systems requiring the 133% insulation level. This exceeds the 100% insulation level requirement. Therefore, the reference to “insulation levels” when describing 5kV cables is unnecessary, and should be omitted (at this voltage) to avoid confusion.

Cables rated over 5kV

Several years ago the terms used to identify the insulation thickness of medium voltage cable for the various voltage ratings were “Grounded” and “Ungrounded.” These terms led the electrical industry to a common but erroneous belief that the type of system grounding determined the insulation level required.

The terms were later replaced in the cable standards with “100% insulation level” and “133% insulation level” respectively which are selected based on the “ground fault protection” of the system. The longer a fault remains on an electrical system the longer the cable is electrically stressed. An effective way of minimizing the stress is by increasing the insulation thickness (to the next level. i.e. 100% & 133%). The relationship of “ground fault protection” to the “insulation level” is best remembered as follows:

— 100% insulation level for fault clearing within 1 minute
— 133% insulation level for fault clearing between 1 minute and one hour
— 173% insulation level for indefinite periods (not currently recognized by CSA)

CSA Technical Section

Standing Voltage

When single conductor metallic covered (sheathed, armored, or shielded) cables are used on AC circuits, the magnetic field of the central conductor will induce a voltage in the metallic covering.

When the individual metal coverings are bonded and grounded at one point only, the induced voltage called "standing voltage" appears at the open ends of the circuit.

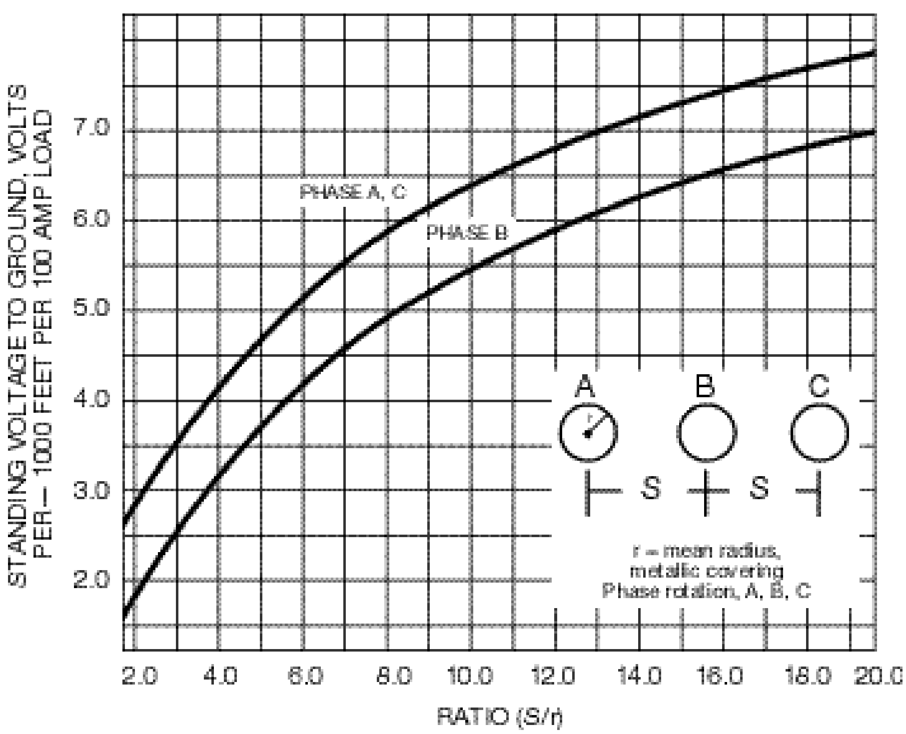
The magnitude of this voltage is in direct proportion to the load current and the cable length and depends on the spacing between the cables. The curves in Figure 1 show the relationship between the induced voltage and the physical dimensions of the system. For equilaterally spaced cables, the magnitude of the induced voltage along each metal covering is the same. However, when the cables are in a flat formation, the magnitude of the induced voltages on the outer phases (A,C) is different from the center phase (B). The curve marked "PHASE B" applies to equilaterally spaced cables also.

The magnitude of the standing voltage is usually limited to about 25 volts. Higher standing voltages may be unavoidable on some installations and may be acceptable and safe if provided for in the design of the installation. One way to limit this voltage, and at the same time increase the circuit length, is to ground the metal covering at the midpoint of the circuit. When the circuit length is so great that the standing voltages cannot be reduced to a safe limit by this method, it becomes necessary to short circuit the metal coverings at the endpoints. The resulting circulating currents are heat generators and must be included in the thermal circuit when computing the system ampacity (see next page).

Transposition or cross-bonding can also be employed to eliminate standing voltages or circulating currents. These systems may give rise to special installation problems.

FIGURE 1

Standing Voltage



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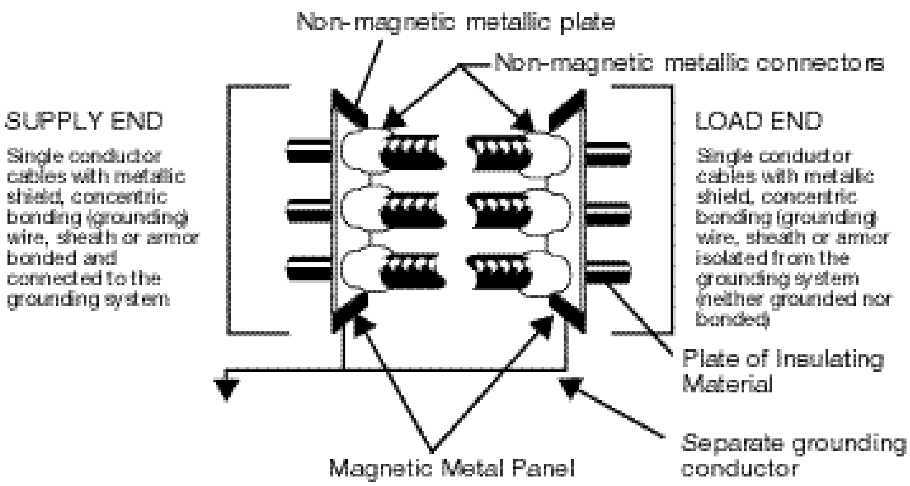
CSA Technical Section

Circulating Currents

When single conductor metallic sheathed or armored cables are connected at more than one point, circulating currents called “sheath currents” will flow through the metallic covering. Sheath currents can be excessive and result in considerable heating of the cable.

In order to avoid overheating, rule 4-008 and Appendix B recommends the following:
- Cables carrying 200 amperes and less:
  no need to derate, sheath losses are minimal.
- Cables carrying 201 to 425 amperes:
  no need to derate if sheath losses are kept to tolerable levels by spacing cables approximately one diameter apart.
- Cables carrying over 425 amperes:
  a) generally necessary to derate the cables to avoid overheating caused by sheath currents, when the metallic sheaths or armors are bonded and grounded at both ends.
  b) no need to derate when the metallic sheaths or armors are bonded and grounded at supply end only, and isolated at load end.

FIGURE 2 **Bonding (Grounding) Alternatives**



125

Figure 2 is a preferred method of limiting sheath current:

Supply End: Cables must enter the panel by means of non-magnetic metal plate (such as aluminum). The metallic shield, bonding (grounding) conductor, metallic sheaths, or armors, shall be adequately bonded and grounded.

Load End: Cables must enter the panel through a plate of insulating material. The metallic shield, bonding (grounding) conductor, metallic sheaths or armors shall be neither bonded nor grounded

Notes:

— CE Code Rule 4-008 Appendix B and CE Code Rule 10-400. When single conductor cables with metallic sheaths or armors are bonded and grounded at one end only, the CE Code requires a separate bonding (grounding) conductor to bond the equipment at each end.

— CE Code Rule 10-302. The PVC covering of TECK90, HVTECK, RA90 and ACWU90 cables is adequate to insulate the metallic sheath or armor from ground. When TECK90, HVTECK, or RA90 are supplied without the overall covering, precautions must be taken to isolate the metallic sheath or armor from ground by installing the cables on insulating supports. Since many steel structures are grounded, the metallic sheath or armor should not make contact with the structural steel or supports.

— CE Code Rule 12-106. The armor of single conductor cables used on AC systems must be of non-ferrous (non-magnetic) material.

— CE Code Rule 12-3026 requires a minimum thickness of 6mm (1/4") for plates installed at the supply end and the load end. Any single conductor cable rated at over 200 amperes must be terminated with non-magnetic connectors, locknut, and bushings, such as aluminum and enter the box or panel via a non-magnetic sub panel or plate.

CSA Technical Section

Single Conductor Cables in Parallel

To make use of the high current carrying capacity of single conductor cable, for heavy loads, it may be desirable to run more than one cable per phase. When this is done, configurations as shown below will theoretically result in equal load sharing.

Neutral may be located outside of the above groups in most convenient location.

All installation of paralleled conductors should comply with the provisions contained in Rule CE Code 12-108 “Conductors in Parallel” and any existing applicable provincial regulations.

Recommended configurations for single conductor cables in parallel -Three Phase Circuits

2 Conductors Per Phase **4 Conductors Per Phase**

Figure 7

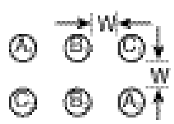


Figure 8

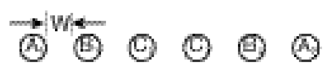
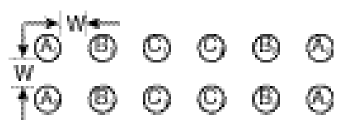


Figure 9



w = cable spacing

The allowable ampacities for the above configurations are subject to conductor spacings, and type of installations.

Cables in Air
For single conductor cable in free air refer to CE Code Rule 12-2212 (Ampacities of Conductors in Cable Trays). Unless other factors apply the rule can be interpreted as follows:

1. “W” greater than one cable diameter, ampacity is in accordance with CE Code Tables 1 or 3
2. “W” 25% to 100% of one cable diameter, ampacity is in accordance with CE Code Tables 1 or 3 modified by CE Code Table 5D for arrangement and number of conductors involved.
3. “W” less than 25% of one cable diameter, ampacity is in accordance with CE Code Tables 2 or 4 modified by CE Code Table 5C for number of conductors involved.

Example: Based on configuration above (Figure 8), when using single conductor 500 kcmil copper, TECK90 1000 Volt cable.
The calculated ampacity is as follows:

1. Spacing greater than cable OD	=	660 amperes
2. Spacing 25-100% cable OD, 660 x .82	=	541 amperes
3. Spacing less than 25% cable OD, 395 x .80	=	316 amperes

Cables Direct Buried or in Ducts
For circuits or portions thereof run underground, the required spacing “W” is much greater than in free air. For ampacity rating please contact General Cable’s Customer Service.

CSA Technical Section

Cable Installation

Cable Supports

Cables should be supported in a workmanlike manner to prevent sagging and strain on the cable. The following distances between supports which should be considered minimum are in accordance with CE Code Rules 12-618 and 12-706.

Cable Type	Distance Between Supports
AC90, ACWU90, TECK90, HVTECK	1.5 M (5 ft)
RA90	2.0 M (6.5 ft)

Note: To avoid the heating effect caused by eddy currents, single conductor cables should not be surrounded by magnetic material. Avoid the use of any magnetic metal clips on steel supports.
The use of aluminum clips is recommended. Black nylon cable ties are recommended for outdoor installations where the environment prevents the use of metallic clips.

Bending Radius

There are two bending radii involved when installing cable.

a) When training into final position (no tension)
b) When installing (pulling with tension)

When Training
Cables without metal coverings (RW90, RWU90, TW75, TWU, TC, T90 Nylon) (i.e. Non-shielded, non-armored)

Cable O.D.	Minimum Bending Radius Multipliers	
0-1 (25.4 mm)	4	ICEA S-95-658, S-96-659 and S-93-693
over 1"	5	(Formerly ICEA S-66-524 Appendix H)

CSA Technical Section

When Training (continued)

Cables with metal coverings (AC90, ACWU90, TECK90, HVTECK, RA90)

Cable Type	Minimum Bending Radius Multipliers	
AC90, ACWU90, TECK90	6 x cable ID CE Code Rule 12-614*	
HVTECK - single conductor	7 x cable OD	CE Code Rule 36-102
- 3 conductor	12 x cable OD**	CE Code Rule 36-102
RA90 (Corrugated Aluminum sheath)	9 x sheath OD CE Code Rule 12-712	
High-Voltage Cable	See Table 15 of CE Code Part 1	

Cable OD = Cable Overall Diameter
Cable ID = Diameter Under the Armor

*Note the diameter referred to here is that measured directly *under* the armor. If not known apply multiplier to cable OD.
**For permanent training *only*, Special permission may be granted by the local inspection authority to use a multiplier of 7 in accordance with ICEA S-95-658, S-96-659 and S-93-639 (Formerly S-66-524 Clause H3.1.3.1)

b) When Installing (Pulling)

There are no known industry standards which establish the minimum size of bends, sheaves, or other curved surfaces around which the cable may be pulled while under tension.

Note: When cables are pulled around bends while under tension, the resultant sidewall bearing pressure (SWBP) can cause damage to the cable. In addition to the bending radius, other factors such as cable weight, pulling tension, friction, and length must be considered to avoid such damage.

Please refer to the next page of this section for information on Pulling Tension and Sidewall Bearing Pressure.

CSA Technical Section

Pulling Tensions

Before commencing to install cables, it is recommended the route be thoroughly checked to ensure bends and pulling tensions will not exceed specified limits. It is important to note that different cable constructions may demonstrate varying degrees of resistance to physical damage. Good raceway design and careful installation practices are essential to ensure long reliable cable performance. The following recommendations are based on a study sponsored by ICEA and reports by other recognized authorities in the engineering of cable installations. The values may be modified if experience and knowledge of a particular installation so indicates.

Maximum Permissible Pulling Tension on Cable:

Pulling eye attached to conductor(s)

Tm = K x n x cmil (Formula 8)

Where: Tm = maximum tension, lbs *

K = constant
= .008 for copper conductors
= .006 for aluminum conductors

n = number of conductors **

cmil = circular mil area of each conductor. (Note: 250 kcmil = 250,000 cmil etc.).

* The maximum pulling tension should not exceed 6500 lbs. or the value obtained using Formula 8, (whichever is lower).
** When pulling a 3 conductor triplexed assembly use N = 2.
When pulling a 3 conductor assembly, with overall jacket, use N = 3.

Cable Grip over finished cable(s):
The maximum pulling tension should not exceed 1000 lbs or the maximum obtained using Formula 8, whichever is lower. The limit applies to one or more cables using one grip.

Note: To avoid displacement of the armor it may be necessary to use a basket grip over the cable in addition to the pulling eyes applied to the insulated conductors.

Calculated Pulling Tension:

Straight section of raceway

Ts = L x W x f (Formula 9)

Where: Ts = Tension at pulling end of straight section (lbs)
L = Length of straight section (ft)
W = Weight of cable (lbs/ft)
f = Coefficient of friction

The coefficient of friction is dependent on the cable exterior covering, raceway material, and type of pulling lubricant. Typically, values between .35 and .50 are experienced for polymeric covered cables installed in clean, smooth, well lubricated raceway. (If unknown use f = .50)

For cables installed in tray using free turning rollers which are spaced to prevent cable from touching the tray, use f = 0.15.

CSA Technical Section

Curved Section of Raceway

When the bending radius of the raceway is small the weight of the length of cable around its curved section may be ignored. For normal bends:

$$T_c = T_f\, e^{fa} \qquad \text{(Formula 10)}$$

Where Tc = Tension of cable at pulling end of curved section, lbs
Tf = Tension of cable at feeding end of curved section, lbs
e = naperian logarithm base (2.718)
f = coefficient of friction
a = angle of bend, radians (1 radian = 57.3 degrees)

Values of e^{fa} for some common angles

ANGLE OF BEND DEGREES	E^{fa}					
	f = .7	f = .6	f = .5	f = .4	f = .3	f = .15
15	1.20	1.17	1.14	1.11	1.08	1.04
30	1.44	1.37	1.30	1.23	1.17	1.08
45	1.73	1.60	1.48	1.37	1.27	1.13
60	2.08	1.87	1.68	1.52	1.37	1.17
75	2.50	2.19	1.92	1.69	1.48	1.22
90	3.00	2.57	2.19	1.87	1.60	1.27

Sidewall Bearing Pressure (SWBP) at Bends

Sidewall bearing pressure is defined as the vector sum of the pressure caused by the tension in the conductor, Tc/R acting horizontally and the weight of the cable acting vertically.
It is given by the expression:

$$P = \sqrt{\quad} \qquad \text{(Formula 11)}$$

Where: P = SWBP (lbs/ft)
Tc = Tension of cable at pulling end of curved section (lbs)
R = Radius of bend (ft)
W = Weight of cable (lbs/ft)

To keep the SWBP within the permissible limits, the tension “Tc” (expressed in lbs) shall not exceed 250 x R. Exception, for Steel Wire Armor (SWA) and Steel Interlocked Armor (SIA) “Tc” shall not exceed 300 x R.

eg: “Tc” maximum for cable in 3 ft radius bend is 3 x 250 = 750 lbs.

For most installations the weight of cable in the bend has little effect on the calculated SWBP due to magnitude of the tension. Neglecting ‘W’ in Formula 11 the expression simplifies to:

$$P = T_c/R \qquad \text{(Formula 12)}$$

CSA Technical Section

Installation of Cable in Tray

With Rollers
The maximum required spacing of rollers along the cable tray route will vary with cable weight, the tension in the cable, the cable construction, and the height of the rollers above the tray bottom.
Near the end of the pull, where the tension is approaching maximum value, the spacing can be greater than at the beginning of the pull, where the tension is at the minimum.
Care must be taken when increasing verticle clearance between cable and tray in attempting to increase spacing between rollers. The tension will increase where heavy cables are allowed to sag between rollers.
Assuming a flexible cable construction, the following expression can be used as an approximation in determining roller spacing:

$$S = \sqrt{\quad} \qquad \text{(Formula 13)}$$

Where: S	=	distance between rollers (ft)
H	=	height of top of roller above tray surface (ft)
T	=	tension (lbs*)
W	=	weight per foot of cables (lbs/ft)

*On long runs it may be necessary to calculate the tension at two or three different points along the run.

Without Rollers
Cables with interlocked armor or cables with corrugated sheath e.g. TECK90, HVTECK, RA90, ACWU90, must not be installed on ladder trays without rollers.

For smooth unarmored types (e.g. Type TC) a coefficient of friction of .25 is suggested. If more than one layer of cable is installed in the tray, and cable is dragged over other installed cables, a coefficient of .5 will yield reasonably accurate results.

Tension at Cable Reel
It is recommended that whenever possible the let-off reel should be rotated to provide slack in the cable, otherwise the tension developed to turn the reel must be taken into account when calculating total tension of the installation.

Tension in Verticle Section
Many cable tray systems are elevated above floor level. If the cable reel is mounted on the floor directly below the starting point of the tray installation, the lifting tension due to the weight of the cable, developed between the reel and tray, must be included in the calculation and is given by the following:

$$T_v = WH \qquad \text{(Formula 14)}$$

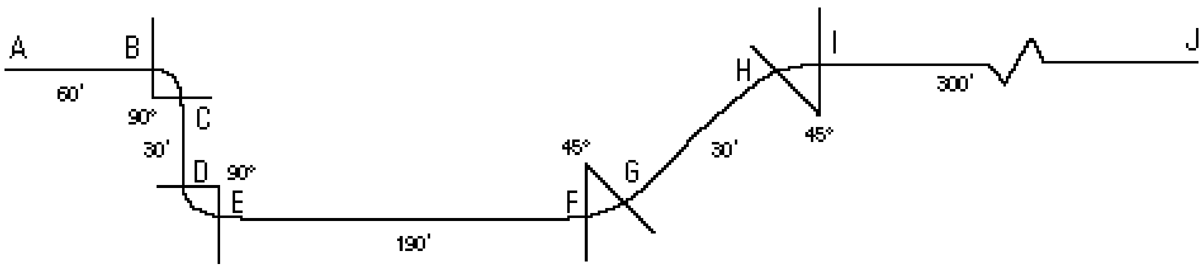
Where: Tv	=	Tension due to cable weight (lbs)
W	=	Weight of cable (lbs/ft)
H	=	Height of lift (ft)

Example Calculation
The total pulling tension comprises the accumulated tensions of the individual straight sections (Ts) and curved sections (Tc) of the raceway as shown in Figure 10:

Cable	=	3/c 500 kcmil copper, XLPE insulated, PVC inner jacket, aluminum interlocked armor, PVC overall covering, 5kV (Unshielded) TECK90
Cable weight	=	6.7 lbs/ft
f	=	.15
Raceway	=	ladder type tray system 36” radius bends
Installation method	=	rollers and sheaves
Cable route	=	horizontal (no verticle bends)

CSA Technical Section

FIGURE 10



Pulling from end J:

Tension at A	= Zero	
Tension at B(Ts1)	= 60 x 6.7 x .15	= 60.3 lbs
Tension at C(Tc1)	= Ts1 e^{fa} = 60.3 x 1.27	= 76.6 lbs
Tension at D(Ts2)	= Tc1 + (30 x 6.7 x .15) = 76.6 + 30.2	= 106.8 lbs
Tension at E(Tc2)	= Ts2 e^{fa} = 106.8 x 1.27	= 135.6 lbs
Tension at F(Ts3)	= Tc2 + (120 x 6.7 x .15) = 135.6 + 120.6	= 256.2 lbs
Tension at G(Tc3)	= Ts3 e^{fa} = 256.2 x 1.13	= 289.5 lbs
Tension at H(Ts4)	= Tc3 + (30 x 6.7 x .15) = 289.5 + 30.2	= 319.7 lbs
Tension at I(Tc4)	= Ts4 e^{fa} = 319.7 x 1.13	= 361.3 lbs
Tension at J(Ts5)	= Tc4 + (300 x 6.7 x .15) = 361.3 + 301.5	= 662.8 lbs

Pulling from end A:

Tension at J	= Zero	
Tension at I(Ts1)	= 300 x 6.7 x .15	= 301.5 lbs
Tension at H(Tc1)	= Ts1 e^{fa} = 301.5 x 1.13	= 340.7 lbs
Tension at G(Ts2)	= Tc1 + (30 x 6.7 x .15) = 340.7 + 30.2	= 870.9 lbs
Tension at F(Tc2)	= Ts2 e^{fa} = 370.9 x 1.13	= 419.1 lbs
Tension at E(Ts3)	= Tc2 + (120 x 6.7 x .15) = 419.1 + 120.6	= 539.7 lbs
Tension at D(Tc3)	= Ts3 e^{fa} = 539.7 x 1.27	= 685.4 lbs
Tension at C(Ts4)	= Tc3 + (30 x 6.7 x .15) = 685.4 + 30.2	= 715.6 lbs
Tension at B(Tc4)	= Ts4 e^{fa} = 715.6 x 1.27	= 908.8 lbs
Tension at A(Ts5)	= Tc4 + (60 x 6.7 x .15) = 908.8 + 60.3	= 969.1 lbs

Observations

Figure 10 (and associated calculations) illustrate a number of points:

1. Feeding at A, the end closest to the first bend, required much less tension than feeding at end J.
2. The cable may be safely pulled with a grip over the cable (de: Tension is within 1000 lbs).
3. When pulling from end A, the resultant tension (Tc4) at B exceeds the recommended maximum tension of 750 lbs (ie: 250 x 3 ft radius) required to keep the SWBP within permissible limits. This may result in damage to the cable components and could affect the performance of the cable.
4. Specific knowledge of the coefficient of friction is important. If f = .3, the pulling tension from end J increases from 662.8 lbs to 1722 lbs resulting in:
   a) A need to use pulling eye attached to conductors
   b) Tension (Tc4) at I is 1120 lbs, well above the recommended maximum required to keep the SWBP within permissible limits
   c) A need to review raceway design (reduce number and/or increase radius of bends).

Note: Any back tension of the "let-off" reel, pullies or any other equipment ahead of the raceway must be included in the calculation.
In the above example, it is assumed the cable is fed onto the tray without tension.

CSA Technical Section

Guides to Cable Pulling Preparation:

First establish the direction of the pull based on safe pulling tensions and sidewall bearing pressure calculations.

Select (and install) the correctly sized pulling grip(s) and swivel(s) based on the calculated pulling tension. See Figure 10.

Locate and position the reels such that cable tension at the feeding end is minimized, using suitable reel mounting equipment.

Select pulling equipment which can provide smooth speed control at the anticipated tensions.

Ensure the pull rope has the required tensile rating. Avoid the use of elastic materials. Steel pull rope is recommended.

Immediately prior to the pulling of cable, ensure that the conduit (raceway) is clean (free of dirt, stones, scale, water, etc.).

For long heavy pulls, prelubrication of conduit and pull rope is essential to prevent abrasion at the bends, particularly plastic conduit bends, which can become soft due to frictional heating.

Important: Install a dynamometer (direct reading type). Some pulling equipment has a built in dynamometer.

Cable Pulling

Provide two-way voice communication and adequate manpower at both feeding and pulling ends of the run. Apply pulling lubricant liberally during the installation of cable in conduit.

Use only CSA approved lubricants that are compatible with the cable outer covering.

For installation in tray, personnel should be stationed at sufficiently close intervals to monitor the movement of the cable during installation.

Accelerate slowly and smoothly from rest to a constant pulling speed in the range of 15 ft/min to 50 ft/min.

The cable should not be allowed to stop midway through the pull; the drag due to friction is greatly increased when pulling is restarted.

Record dynamometer readings at frequent intervals during each pull.

Cold Temperature Installations

Cables manufactured to CSA standards are subjected to low temperature cold bend and cold impact laboratory tests. Compliance with these test requirements enables the manufacturer to print a low temperature marking on the cable (eg –40˚C).

This low temperature marking should not be interpreted as the minimum cable installation temperature. The actual rigors of cable installation may surpass the test performance parameters associated with the laboratory test conditions. Cable damage may result.

General Cable recommends that when necessary to install cable at temperatures below –10˚C the material should first be stored in a heated building for 48 hours prior to the cable pull. The cables will then be easier to install and less prone to damage.

After the Pull

Seal the ends of the installed cable and the ends of unused cable remaining on the reel, pending splicing or terminating, to prevent ingress of moisture.

Observe the minimum bending radius when training cable into final position. Secure cables to trays, vertical risers, poles, etc., using fasteners which provide adequate support with minimum amount of pressure.

Ensure that only non-ferrous fasteners are used on single conductor power cables.

Provide suitable mechanical protection during project construction for cables which are vulnerable, such as those in tray or open trench.

High voltage testing is recommended immediately before and after installation.

CSA Technical Section

Vertical installations

It is recognized that Teck cable systems are run both horizontally and vertically. Sometimes concern is expressed about the potential problems of “core-slippage” when standard TECK90 cable is installed vertically. Under certain conditions when gripping force (tightness of the armor) is exceeded by the weight of the cable core, slippage can occur. The tightness of the armor in standard TECK90 cable will vary, dependent upon the size of the cable and normal manufacturing tolerances. The armor is applied sufficiently snug to allow expansion and contraction and permit easy removal for splicing and terminating.

A precise armor gripping force cannot be determined, therefore, a formula to calculate the height limitations for standard TECK90 is not available. Determination of the appropriate cable design (TECK90 or VERTITECK®) is left to the judgement of the system designer. Here are a few conditions which indicate the use of VERTITECK®.

1. Where the vertical portion of the cable run is longer than the horizontal portion.
2. Riser Cables in highrise buildings.
3. Cable installed in mineshafts where permitted as an alternative to conventional Steel Wire Armored (SWA) cable.
4. Long circuits where the calculated pulling tensions or sidewall pressures around bends are excessive.

The maximum self-supporting lengths (MSSL) of VERTITECK® is calculated using the following formula:

$$\text{MSSL (m)} = \frac{13.2 \times n \times c\ mil}{f \times m}$$

where:

c mil	=	circular mil area of the copper phase conductor *
n	=	number of phase conductors in the cable
m	=	mass of the cable per unit length (kg/km)
f	=	safety factor
	=	5 for mine shaft cable (as per ICEA S66-524)
	=	7 for riser cable (as per ICEA S66-524)

*please refer to the table for circular mil area of conductor

Notes:
1. To convert MSSL from m to ft, multiply the value by 3.281.
2. The strength of the stranded copper conductors is based on a tensile strength of 255 mpa (37,000 psi).
3. The MSSL permits the cable to be supported by the phase conductors (during installation).

VERTITECK® is only self-supporting during installation. The cable must be clamped to the walls at regular intervals. Based on the Canadian Electrical code requirements, the cables must be clamped at 1.5 m intervals for horizontal runs and 6 m intervals for vertical runs.

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